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ORIGINAL PAPER

Edge effects on plant diversity in tropical forest ecosystems at Periyar Wildlife sanctuary in the Western Ghats of India

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Abstract: Forest resource conservation has been widely accepted as a key to sustain the local and regional economic development. The forest edges are affected by anthropogenic activities including deforestation, forest fragmentation, selective logging, extraction of non-timber forest products, collection of medicinal plants, recreations, hydroelectric projects and its associated developmental activities, which alter the biodiversity. The present study intends to evaluate the edge effect on vegetation structure and species compositions in the tropical forest ecosystems at Periyar Wildlife Sanctuary in the Western Ghats. High species richness (number of species) and Shannon's diversity indices were observed in the site III (completely undisturbed forest) compared to site I (adjacent to the village/ edge of the forest, which is next to the teak plantation, severely disturbed forest) and site II (in between the undisturbed forest and moderately disturbed forest) while density of tree species showed greater value in site II. Single species such as *Tectona grandis* (IVI of 80) and *Terminalia paniculata* (IVI of 112) were the dominant tree species in site I and site II, respectively, whereas, in site III *Terminalia bellirica, Bishofia javanica* and *Syzgium gardneri* shared the dominance. Perturbation leads to alien plant invasion particularly *Lantana camara, Eupatorium odoratum* and *Ageratum conizoides*. Site II is at forest transition level because the site is dominated by both natural species as well as plantation species such as *Tectona grandis*. This site seems to be a buffer zone on natural forest and plantations. Further studies are required to analyse the real patterns of regeneration and dynamic change due to human impact by long term monitoring with the establishment of permanent plots.

Key words: anthropogenic disturbance; biodiversity; edge effect; tropical forest; Western Ghats

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Introduction

The ecological, social, economic, cultural and aesthetic values of biodiversity have been widely recognised (Pimm et al. 1995; Mittermerier et al. 1999). Biodiversity is being significantly reduced by anthropogenic perturbations; however, land use change is the main threat (Mittermerier et al. 1999). Researchers estimate that the clearing of half of the world's remaining forests would eliminate 85% of all the species inhabited by them (Pimm and Raven 2000). For the past few decades, the significance of this threat has led to a growing awareness of the importance of biodiversity and habitat conservation. Hence conservationists focused on identifying prime conservation areas as a key to conserving the planet's disappearing species, genes, and ecosystems (Prendergast et al. 1999; Shi et al. 2005). Their continuous effort of research work has resulted in the identification of 17 megadiverse countries (Mittermerier et al. 1997) and 25 biodiversity hotspots (Mittermerier et al. 1999; Myers et al. 2000).

As per the survey in 1995, more than 1.1 billion people were found to inhabit biodiversity hotspots. The annual population growth rate of 1.8% in these hotspots (1995-2000) was substantially higher than the annual global population growth rate of 1.3% (Cincotta et al. 2000). Alarming growth rate of population in developing countries, owing to their increased demand for land, material products, and development projects, threaten natural habitats (Sahu et al. 2008; Htun et al. 2010; Thapa and Chapman 2010; Htun et al. 2011). The most serious consequences of further habitat loss occur in hotspot areas, which are high in species endemism and low in pristine vegetation. Hence, conservation biologists, including Myers et al. (2000), have called for immediate steps to conserve these hotspots (Myers 1990; Shi et al. 2005).

A central focus in plant ecology is to understand the mechanisms controlling plant community structure and dynamics (Crawdey 1997). Vegetation assemblages are complex units involving myriads of interrelating processes at various levels of biological organization. Nevertheless, the similarity of pattern in community structure with respect to environmental gradients

across sites (Whittaker 1975) suggests the existence of unified underlying principles (Tilman 1990; Huston 1994). Over the last decades a number of processes have been described as critical for species richness maintenance in plant communities; chiefly environmental heterogeneity originated from both biotic or abiotic sources (Tilman 1982), spatial processes (Pacala 1997) and chance (Hubbell 2001).

Landscape matrix surrounding the protected areas has received much attention recently from the conservation point of view (Haplin 1997; Hannah et al. 2002). Very few ecological studies are available on comparison of protected areas and its surrounding matrix (Khan et al. 1997; Velazquez et al. 2003; Bhagwat et al. 2005). However, Understanding the species distribution and its functional attributes of protected areas and its surrounding areas are important for the management and conservation of biodiversity (Roy 2003). When forest expansion occurs through the conversion of fields or scrub growth into plantation of monocultures, as it has many forest scare nations, the expansion of biodiversity from monoculture plantation to a forest transition can be quite small (Spellerberg 1996). The re-emergence of secondary forests on uncultivated lands allows many species to recolonize an area by extending the range of some species through migration and seed dispersal, regrowth probably reduces ecological fragmentation and prevents additional extinctions (Schelhas and Greenberg 1996). For the conservation and wise use of these forests, a greater understanding of their biodiversity is required (Van Andel 2001). Unfortunately, there are still many gaps in this knowledge that to be filled in order to develop a sound management system (Nasir et al. 1997as cited in Van Andel 2001). Understanding the impact of anthropogenic pressure, including hydroelectric projects, conversion of plantations and other developmental activities, on the forest is urgently needed to address the site-specific conservation problems and sustainable use of natural resources. Therefore, the present study intended to evaluate the impact of disturbance on plant biodiversity in tropical forest ecosystems at Periyar Wildlife Sanctuary in the Western Ghats. The results of this research would provide baseline data for sustainable maintenance and ways to identify the key factors to conserve the natural resources in the future.

Material and methods

Study area

The study area, Periyar Tiger Reserve (Periyar Wildlife Sanctuary), is located in Idukki district, the largest district of Kerala with an area of 4,998 km^2. It lies between 9°16′–9°36′ North latitude and 76°57′–77°25′ East longitude. The reserve has an area of 777 km^2 including the Periyar Lake (named after the Periyar river) and an area of 26 km^2. Periyar river is the longest river in Kerala, which flows across the reserve. Periyar Wildlife Sanctuary has undulating hills ranging in altitude from 100 m (Pambavalley) to 2,016 m (Vellimala) above sea level. The prominent peaks are Pachayarmala, Vellimala, Kottamala, Sunderamala, Chokkampettimala and Karimala. Topographically the reserve can be divided into two parts, the South Eastern part and the Western part. The South-Eastern part (Thekkady Range), which is the water shed area to Periyar Lake, is bordered with two hill ranges: (a) the *Chokkampetti-Vellimala-Eravanglar-Mangaladevi* hill range and (b) the *Odamala-Sundaramala-Melmala* hill range.

Periyar Wildlife Sanctuary belongs to climatic regions of India where the rainfall is above 2500 mm per year and has a humid climate without much seasonal variation. The temperature varies between 15°C and 31°C with April-May being the hottest months and December-January the coolest. This area receives the South-West and the North-East monsoons, the former during June-September and the latter during October-November months, with the maximum rainfall in July and the minimum in February (Fig. 1). The average rainfall recorded in the range was 2090 mm per annum.

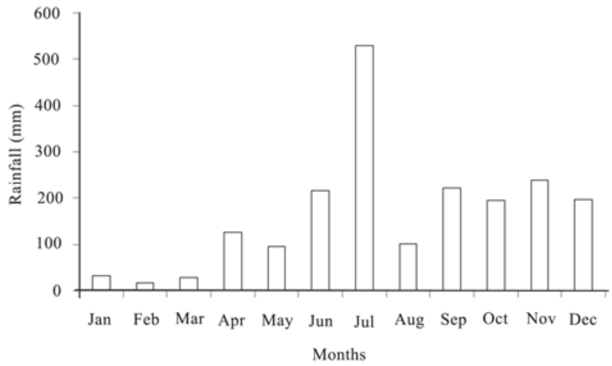

Fig. 1 Rainfall Pattern of the study area at the Periyar Wildlife Sanctuary in the Western Ghats, India

The sanctuary is enriched with an equatorial type of vegetation, not much different from other windward side forests of the Western Ghats. According to the classification of Champion and Seth (1968), the vegetation of the Sanctuary can be classified into the following types: (1) west coast tropical evergreen forests (evergreen), (2) west coast semi-evergreen forests (semi-evergreen), (3) southern moist mixed deciduous forests (moist deciduous), (4) southern hill-top tropical evergreen forests (hill-top evergreen), (5) southern montane wet temperate forests (shola)

Around 100 km^2 of the Reserve is under Southern Moist mixed deciduous forests type. In Periyar Wildlife Sanctuary, this forest type is found up to an altitude of 1200 m and is again peculiar in having scattered evergreen tree species viz., *Litsea coriacea, Olea dioica*, etc. The trees shed their leaves during hot months and the burnt out appearance may last for 6–8 weeks. This forest was found at Thaannikkudy, Mullakkudy, Edappalayam, Pambavalley and Methaganam areas.

Southern Moist mixed deciduous forests

The three-tier canopy structure is discernible in these forests. The upper canopy trees are *Pterocarpus marsupium, Tectona grandis, Terminalia paniculata, Terminalia crenulata, Bombax ceiba,*

Terameles nudiflora, Actinodaphne malabaricum, Grewia tilifolia, Lagerstroemia microcarpa, Sterculia villosa, etc. In Pamba-valley (below 100 m) this forest is characterized by the Xylia-Adina-Terminalia association, where the major trees are *Xylia xylocarpa, Adina cordifolia, Terminalia elliptica, T. paniculata, Lannea coromandelica, Bridelia airy-shawii* etc. Middle canopy trees are *Olea dioica, Litsea coriacea, Careya arborea, Dillenia pentagyna, Buchanania lanzan, Phyllanthus emblica, Glochidion ellipticum, Glochidion tomentosum,* etc. The lower storey trees are *Wrightia tinctoria, Helicteres isora, Catunaregum spinosum, Clausena dentata,* etc. The shrubby layer is composed *of Maesa indica, Solanum torvum, Solanum anguivi, Lantana camara, Ixora malabarica, Pavetta tomentos, Desmodium pulchellum, Chromolaena odorata,* etc. Climbers like *Spantholobus purpureus, Combretum ovalifolium, Calycopteris floribunda, Combretum ovalifolium, Cissus repens* are very common in these forests. Many exotic weeds like *Mikania cordifolia, Mimosa diplotricha* were also found gregariously growing in these forests (Jomy 2000).

The present study was carried out in the Methaganam areas of Mangaladevi hills. The study was restricted to the lower part of the hills due to a short study period.

Methods

Three study sites were selected in the forest ecosystem based on disturbance gradient. The study site I is a severely disturbed region, very close to the Teak plantations, which are in between the human settlements and natural forests. Since site I is closer to the human settlement, unofficial cattle grazing and other anthropogenic disturbances are quite common. The site II lies in between site I and site III, and moderately disturbed forest which is subjected to occasional dry wood collections by tribal peoples. These sites (I & II) are closer to a road (metal road) laid by the forest department. The road is utilized by forest department and government officials for checking various developmental activities and also used by common people for pilgrimage to Kannaki temple once in a year during festival time. Site III is completely undisturbed natural forest.

Phytosociological studies (Mishra 1968; Kershaw 1973) were conducted in three study sites in the tropical forest ecosystems at Periyar Wildlife Sanctuary in the Western Ghats. In each study sites, three sub-plots were selected for the vegetation analysis. The density, frequency, basal area and importance value index (IVI) were estimated at each sub-plot through a transect (1 km; 10×10 m^2 quadrates at an interval of 100 m) for trees (individuals with diameter at breast height (DBH) more than 10 cm). A similar number of 5 m × 5 m size quadrates were laid in the same transect of each sub-plot to study tree seedlings (< 3 cm DBH), saplings (> 3 – < 10 cm DBH), and shrubs. Climbers of all sizes, whose base fell inside the quadrates (5×5 m^2) were enumerated. However, for the study of herbaceous community, thirty 1×1 m^2 size quadrates were placed in the same transect in each sub-plot. All epiphytes were not sampled in this study. The plant samples were identified using flora books by Gamble (1925) and Pascal and Ramesh (1987) and confirmed with Regional BSI, Coimbatore. Species diversity index was calculated using a formula given by Margalef (1968) and Spellerberg and Fedor (2003) as:

$$H^1 = \sum (n_i / N) \ln(n_i / N)$$

where H^1 = Shannon's index of general diversity; n_i = importance value index of species I, N = importance value index of the community.

The index of dominance of the community was calculated by Simpson's index (Simpson 1949) as:

$$c = \sum (n_i / N)^2$$

where c = index of dominance; n_i and N being the same as in the Shannon's Weiner index of general diversity.

The index of the species richness (d) was calculated following Menhinick (1964) as:

$$d = S / \sqrt{n}$$

where S = number of species; n = number of individuals.

The evenness index of the community (e) was calculated following Pielou (1966) as:

$$e = H^1 / \log S$$

where S = number of species; H' = Shannon's index.

One way ANOVA was used to test for differences among the study sites in various phytosociological characteristics.

Results

A total of 174 plant species of 135 genera and 63 families were recorded from the three study areas. The numbers of species were greater in the undisturbed forest (site III; 92) compared to the study site II and site I (Table 1, 3). Tree density and basal area showed greater value in the moderately disturbed forest site (site II) compared to the other two sites. In the case of shrubs and herbs, greater density and basal area was observed in the severely disturbed forest site (site I) followed by site II and site III except basal area of herbs whereas, the reverse trend was observed in the case of climbers. Shannon's diversity index of trees and shrubs showed the greater value in the site III followed by site II and site I (Table 2, 3). In contrast, dominance index of trees were greater in the site II compared to the site I and site III. However, the dominance index of shrubs was greater in the site I compared to the other study sites. Similarly, in herbs diversity index showed greater value in the site I compared to other study sites, while reverse trend was observed in case of dominance index in herbs. Species richness value was greater in the site III compared to the site II and site I except for climbers. A similar trend was recorded in the evenness index of tree saplings and seedlings populations, shrubs and herbs while adult trees and

climbers showed greater values in the site I compared to other sites.

Table 1. Number of species, density and basal area of higher plants in different disturbance regimes at Periyar Wildlife Sanctuary in the Western Ghats

Criteria	Severely disturbed				Moderately disturbed				Undisturbed			
No. of species (Total No./ 0.3 ha)	80				84				92			
	*SP1	SP2	SP3	Total	SP1	SP2	SP3	Total	SP1	SP2	SP3	Total
Number of species – item wise												
Trees (No./0.1ha)	14	12	12	20	6	10	10	12	18	16	15	31
Saplings (No./0.025ha)	8	7	10	13	10	12	10	22	17	18	13	34
Seedlings (No./0.025ha)	18	16	17	26	19	17	14	30	8	18	9	25
Shrubs (No./0.025ha)	14	8	9	21	6	9	5	11	11	5	3	15
Climbers (No./0.025ha)	3	1	3	5	3	6	3	10	3	3	3	5
Herbs (No./m^2)	18	14	13	22	8	16	7	18	5	6	8	12
Density N (No./ha)												
Trees	410	490	500	466.7	610	500	470	530	540	410	380	443
Saplings	2240	2880	7320	4147	3040	4880	5480	4467	3320	4400	5880	4520
Seedlings	5920	5000	11120	7347	1640	1680	5280	2867	600	3040	680	1440
Shrubs	7920	5280	10320	7840	3600	4480	4040	4040	920	360	520	600
Climbers	600	40	1040	560	400	720	3120	1413	2120	2200	2600	2307
Herbs (No./m^2)	56.9	55.3	59.4	57.2	27.4	35.5	37.8	33.7	9.8	12.6	15.7	12.7
Basal Area (m^2/ha)												
Trees	35.85	27.31	33.72	32.54	51.29	56.67	40.57	49.51	52.15	41.48	39.29	44.34
Saplings	1.88	0.49	7.16	4.64	1.83	4.39	3.53	3.12	2.43	3.12	2.92	2.82
Seedlings	0.15	0.08	0.22	0.15	0.20	0.04	0.14	0.13	0.02	0.07	0.02	0.04
Shrubs	1.25	0.67	3.14	1.69	1.32	0.99	0.47	0.93	0.17	0.03	0.20	0.13
Climbers	0.002	0.000	0.015	0.006	0.006	0.005	0.013	0.008	0.05	0.06	0.05	0.05
Herbs (cm^2/m^2)	18.00	15.94	14.01	48.07	10.41	14.13	14.71	39.25	21.53	13.39	17.03	51.95

*SP refers to sub-plot.

Table 2. Diversity, dominance, evenness index and species richness of plant community in different disturbance regimes at Periyar Wildlife Sanctuary in the Western Ghats

Criteria		Severely disturbed				Moderately disturbed				Undisturbed			
		*SP1	SP2	SP3	Total	SP1	SP2	SP3	Total	SP1	SP2	SP3	Total
Shannon index	Trees	2.316	2.341	1.975	2.466	1.624	1.625	1.952	1.874	2.332	2.421	2.151	2.546
	Saplings	1.550	1.617	1.929	1.917	1.900	1.696	1.641	2.018	2.105	2.167	1.990	2.678
	Seedlings	2.209	2.255	2.406	2.491	2.527	2.398	2.221	2.793	1.711	2.686	2.120	2.811
	Shrubs	1.888	1.357	1.568	1.831	1.684	1.759	1.324	1.757	2.084	1.420	0.928	2.301
	Climbers	1.031	0.000	1.038	1.308	0.949	1.429	0.755	1.356	0.472	0.408	0.353	0.465
	Herbs	2.347	2.123	1.974	2.306	1.692	2.054	1.560	1.935	1.385	1.496	1.559	1.875
Dominance index	Trees	0.125	0.108	0.208	0.122	0.212	0.314	0.179	0.208	0.131	0.110	0.178	0.125
	Saplings	0.313	0.256	0.184	0.208	0.196	0.287	0.255	0.210	0.223	0.170	0.186	0.145
	Seedlings	0.170	0.140	0.111	0.116	0.123	0.141	0.140	0.085	0.264	0.080	0.129	0.081
	Shrubs	0.229	0.380	0.273	0.269	0.205	0.233	0.308	0.228	0.166	0.289	0.432	0.133
	Climbers	0.381	1.000	0.372	0.325	0.441	0.317	0.576	0.447	0.767	0.807	0.839	0.808
	Herbs	0.136	0.165	0.194	0.154	0.233	0.178	0.248	0.203	0.272	0.285	0.281	0.213
Species richness	Trees	2.19	1.71	1.70	1.69	0.77	1.41	1.46	0.95	2.45	2.50	2.43	2.69
	Saplings	1.07	0.82	0.74	0.74	1.15	1.09	0.85	1.20	1.87	1.72	1.07	1.84
	Seedlings	1.48	1.43	1.02	1.11	2.97	2.62	1.22	2.05	2.07	2.06	2.18	2.41
	Shrubs	0.99	0.70	0.56	0.87	0.63	0.85	0.50	0.63	2.29	1.67	0.83	2.24
	Climbers	0.77	1.00	0.59	0.77	0.95	1.41	0.34	0.97	0.41	0.40	0.37	0.38
	Herbs	0.75	0.60	0.53	0.53	0.48	0.85	0.36	0.57	0.51	0.53	0.64	0.61
Evenness index	Trees	2.02	2.17	1.83	1.90	2.09	1.63	1.95	1.74	1.86	2.01	1.83	1.71
	Saplings	1.72	1.91	1.93	1.72	1.90	1.57	1.64	1.50	1.71	1.73	1.79	1.75
	Seedlings	1.76	1.87	1.96	1.76	1.98	1.95	1.94	1.89	1.89	2.14	2.22	2.01
	Shrubs	1.65	1.50	1.64	1.38	2.16	1.84	1.89	1.69	2.00	2.03	1.95	1.96
	Climbers	2.16	0.00	2.18	1.87	1.99	1.84	1.58	1.36	0.99	0.86	0.74	0.67
	Herbs	1.87	1.85	1.77	1.72	1.87	1.71	1.85	1.54	1.98	1.92	1.73	1.74

*SP refers to sub-plot.

Table 3. ANOVA application of various characteristics of phytosociological analysis in different disturbance regimes in the tropical forest ecosystems at the Periyar Wildlife Sanctuary in the Western Ghats, India.

Characteristics	Mean values Site I	Site II	Site III	F	P value	Level of significance
Number of species						
Trees (No./0.1ha)	12.67	8.67	16.33	14.704	0.005	**
Saplings (No./0.025ha)	8.67	10.67	16.00	10.211	0.012	**
Seedlings (No./0.025ha)	17.00	16.67	11.67	2.133	0.200	NS
Shrubs (No./0.025ha)	10.33	6.67	6.33	1.385	0.320	NS
Climbers (No./0.025ha)	2.33	4.00	3.00	1.462	0.304	NS
Herbs (No./m^2)	15.00	10.33	6.33	5.030	0.052	NS
Density (No./ha)						
Trees	466.7	526.7	443.3	1.102	0.391	NS
Saplings	4146.7	4466.7	4533.3	0.035	0.966	NS
Seedlings	7346.7	2866.7	1440.0	4.976	0.053	*
Shrubs	7840.0	4040.0	600.0	17.798	0.003	**
Climbers	560.0	1413.3	2306.7	2.716	0.145	NS
Herbs (No./m^2)	57.2	33.6	12.7	104.179	0.000	***
Basal Area (m^2/ha)						
Trees	32.29	49.51	44.31	5.226	0.049	*
Saplings	3.18	3.25	2.82	0.033	0.968	NS
Seedlings	0.15	0.13	0.04	2.628	0.151	NS
Shrubs	1.69	0.93	0.13	2.919	0.130	NS
Climbers	0.01	0.01	0.05	54.767	0.000	***
Herbs (cm^2/m^2)	15.98	13.08	17.32	1.618	0.274	NS
Shannon's index						
Trees	2.211	1.734	2.301	8.674	0.017	*
Saplings	1.699	1.746	2.087	5.991	0.037	*
Seedlings	2.290	2.382	2.172	0.363	0.710	NS
Shrubs	1.604	1.589	1.477	0.094	0.912	NS
Climbers	0.690	1.044	0.411	1.886	0.232	NS
Herbs	2.148	1.769	1.480	9.316	0.014	*
Dominance index						
Trees	0.147	0.235	0.140	2.806	0.138	NS
Saplings	0.251	0.246	0.193	1.319	0.335	NS
Seedlings	0.140	0.135	0.158	0.129	0.882	NS
Shrubs	0.294	0.249	0.296	0.241	0.793	NS
Climbers	0.584	0.445	0.804	2.004	0.216	NS
Herbs	0.165	0.220	0.279	13.117	0.006	**
Species richness						
Trees	1.867	1.213	2.460	15.365	0.004	**
Saplings	0.877	1.030	1.553	4.807	0.057	NS
Seedlings	1.310	2.270	2.103	2.558	0.157	NS
Shrubs	0.750	0.660	1.597	3.900	0.082	NS
Climbers	0.787	0.900	0.393	1.924	0.226	NS
Herbs	0.627	0.563	0.560	0.153	0.861	**
Evenness index						
Trees	2.007	1.890	1.900	0.401	0.687	NS
Saplings	1.853	1.703	1.743	1.196	0.365	NS
Seedlings	1.863	1.957	2.083	2.736	0.143	NS
Shrubs	1.597	1.963	1.993	11.463	0.009	**
Climbers	1.090	1.710	0.800	0.536	0.632	NS
Herbs	1.830	1.810	1.877	0.384	0.697	NS

*0.05 level; **0.01 level; *** 0.001 level; NS- non significance

Taxonomically, the numbers of families were greater in the site III (45) compared to the other two study sites (site II, 39 and site I, 40; Table 4). Twenty-seven families were common among all the three study sites. Thirty-one families were common between site I and site II. Thirty families were common between the site II and Site III. Twenty-eight families were common between site I and site III. A similar trend was also observed as in the case of genera. The greater number of genera was in the site II and site III (78 genera) compared to site I (74 genera in site I). Eighteen families in the site I, 14 families in the site II and 16 families in the site III were represented by only one individual species.

The dominant family in terms of the number of species in the site I was Euphorbiaceae followed by Compositae, Graminae, Lauraceae and Verbenaceae, whereas in site II, Lauraceae and Euphorbiaceae were the dominant family followed by Papilionatae, Compositae, Combretaceae and Zingiberaceae. In the site III, Euphorbiaceae was the dominant family followed by Lauraceae, Rutaceae, Graminae, Combretaceae and Moraceae.

The dominant tree species in the site I was *T. grandis* followed by *T. paniculata, Anogeissus latifolia* and *Actinodaphne malabarica*, whereas in site II, *T. paniculata* was the dominant tree species followed by *A. malabarica*, *Canthium parviflorum* and *T. grandis* (Table 5). However, in the site III, *Terminalia bellirica* was the dominant species followed by *Bischofia javanica, Syzygium gardneri* and *Eleocarpus tuberculatus*. Four tree species were common among all the three study sites. Nine species were common between site I and site II, three species were common between site I and site III and three species were common between site II and site III.

With increasing tree size (>10 cm DBH) classes, species richness (number of species per 0.3 ha), and density (No./0.3 ha) decreased in the site I and site III (Table 6) while site II did not show any specific trend. More or less a similar trend was observed in tree juvenile population size (>1 cm - <10 cm DBH) class distribution except density in site III (Table 7). The lowest size class of tree, 10–20 cm DBH, considered in the present study contributed more than forty percentage of the total tree density. However, medium sized adult trees (10–40 cm DBH) contributed sixty-six percent in site II, while this size class contributed seventy-seven percent in site III and eighty-four percent in site I. About one third of the species (16 out of 48 tree species in site I; 27 out of 64 in site III) figured in the lowest diameter class (10–20 cm DBH). However, in site II, this size class contributed in one fifth of tree species. Only a few large (>90 cm DBH) size trees were recorded in these forests. Size class distributions of some dominant plant species are presented in Fig. 2a-2c. Only a few dominant species showed 'L' shaped curves (*T. paniculata, A. malabarica, C. spinosum, A. latifolia, C. parviflorum, E. tuberculatus*) while a few of them showed 'J' shaped curves (*B. javanica, S. gardnerii*). However, a few of them did not show any specific trends.

Table 4. Family-Wise contribution of genera (G), species (S) and density (No./0.3ha) in the Tropical forest ecosystems at Periyar Wildlife Sanctuary in the Western Ghats, India.

Families	Severely disturbed			Moderately disturbed			Undisturbed		
	G	S	D	G	S	D	G	S	D
Acanthaceae	1	1	36	2	2	7	1	1	1
Amarathaceae	-	-	-	1	1	137	-	-	-
Amaryllidaceae	1	1	15	-	-	-	-	-	-
Anacardiaceae	1	1	3	-	-	-	1	1	1
Anonaceae	1	1	1	-	-	-	1	1	2
Apocyanaceae	-	-	-	2	2	2	2	2	2
Aristolochiaceae	-	-	-	-	-	-	1	1	1
Asclepidaceae	2	2	17	1	1	1	-	-	-
Bignoniaceae	-	-	-	-	-	-	1	1	1
Burseraceae	-	-	-	2	2	4	-	-	-
Caesalpinoideae	-	-	-	2	2	91	-	-	-
Caprifoliaceae	1	1	3	1	1	1	3	3	11
Celastraceae	-	-	-	1	1	1	-	-	-
Chloranthaceae	-	-	-	-	-	-	1	1	3
Cochlospermaceae	1	1	13	-	-	-	-	-	-
Combretaceae	3	3	88	4	5	71	3	4	26
Commenlinaceae	-	-	-	-	-	-	1	1	1
Compositae	5	5	122	4	4	125	1	1	9
Cyperaceae	2	2	98	1	1	7	1	1	9
Datiscaceae	-	-	-	-	-	-	1	1	4
Dilleniaceae	-	-	-	1	1	1	-	-	-
Dioscoriaceae	-	-	-	1	1	1	-	-	-
Dipterocarpaceae	-	-	-	-	-	-	1	1	8
Ebenaceae	1	2	3	1	1	1	3	4	22
Eleocarpaceae	-	-	-	-	-	-	1	1	11
Euphorbiaceae	12	13	132	9	9	36	13	15	53
Fabaceae	4	4	23	-	-	-	1	1	1
Flacouratiaceae	-	-	-	4	4	148	5	6	49
Graminae	4	4	933	2	2	619	5	5	215
Hypoxidaceae	1	1	88	-	-	-	-	-	-
Icacinaceae	2	2	2	1	1	2	2	2	2
Lauraceae	10	10	334	10	12	183	10	11	39

Families	Severely disturbed			Moderately disturbed			Undisturbed		
	G	S	D	G	S	D	G	S	D
Lillaceae	1	1	13	2	2	5	2	2	2
Lythraceae	3	3	7	1	1	1	-	-	-
Malavceae	2	2	32	2	2	7	-	-	-
Melastomataceae	-	-	-	-	-	-	1	2	3
Meliaceae	-	-	-	1	1	6	3	3	5
Menispermaceae	1	1	10	-	-	-	-	-	-
Mimosoideae	1	1	15	3	3	8	-	-	-
Moraceae	-	-	-	1	1	1	2	4	9
Myristicaceae	-	-	-	-	-	-	1	1	1
Myrsinaceae	1	1	246	1	1	94	1	1	11
Myrtaceae	3	3	31	2	3	20	1	1	19
Oleaceae	4	4	89	1	1	4	4	4	7
Palmaceae	-	-	-	-	-	-	1	1	2
Papilionatae	4	6	9	4	6	47	2	3	5
Piperaceae	1	1	16	1	1	87	2	2	179
Polygonaceae	1	1	15	-	-	-	-	-	-
Polypodiaceae (pteridophytes)	1	1	112	1	1	129	1	1	131
Rhamnaceae	1	1	1	2	2	6	-	-	-
Rubiaceae	5	5	174	7	7	93	3	3	156
Rutaceae	1	1	87	-	-	-	9	11	103
Santalaceae	2	2	8	-	-	-	-	-	-
Sapindaceae	1	1	1	1	1	1	2	2	2
Solanaceae	1	1	1	1	1	1	1	1	1
Sterculiaceae	1	2	2	3	3	33	1	1	1
Tiliaceae	3	4	95	2	2	2	2	2	2
Umbelliferae	1	1	1	-	-	-	-	-	-
Urticaceae	-	-	-	-	-	-	3	3	33
Verbenaceae	5	5	171	3	3	36	4	4	19
Vitaceae	-	-	-	-	-	-	1	1	2
Xanthophyllaceae	-	-	-	-	-	-	2	2	2
Zingiberaceae	3	3	301	3	4	102	1	1	10

Table 5. Importance value index (IVI) of different plant categories in the tropical forest ecosystems at the Periyar Wildlife Sanctuary in the Western Ghats, India.

Name of species	Severely disturbed				Moderately disturbed				Undisturbed			
	SP1	SP2	SP3	Total*	SP1	SP2	SP3	Total*	SP1	SP2	SP3	Total*
Trees												
Actinodaphne malabarics Balakr.	17.38	20.10	28.34	22.07	61.41	44.84	43.67	49.93	7.83	5.25	8.52	7.46
Anogeissus latifolia (Roxb.ex DC.) Wall.ex.Guill. & Perr.	39.68	26.56	39.23	35.15		8.84	11.52	6.67		9.81		3.07
Antideama menasu Miq.											6.11	1.75
Antidesma acidum Retz.	15.66		11.57	8.94						5.86		1.85
Bischofia javanica Bl.									58.16	43.97	49.43	51.81
Bridelia roxburghiana Gehm.	7.01			2.17								
Buchanania lanzan Spreng.		14.23	5.58	6.54								
Canthium parviflorium Lam.	16.59			4.70	70.23	26.77	34.31	44.03				
Casearia ovata (Lamk.) Wild.											5.85	1.68
Catunaregam spinosum (Thunb.) Tirveng.	29.98	10.33	24.67	22.66								
Chionanthus mala-elengi Dennst.									4.03			1.69
Cinnamomum malabatrum (Burm.f.) Bl.											5.97	1.71
Clausena dentata (Wild.) Roem.											6.23	1.79
Clausena heptaphylla (Roxb.)Wight & Arn											5.88	1.69
Dillenia pentagyna Roxb.						6.80		2.17				
Diospyros sylvatica Roxb.									8.16			2.55
Elaeocarpus tuberculatus Roxb.									49.24	46.98	15.24	38.98

Continued to Table 5

Name of species	Severely disturbed				Moderately disturbed				Undisturbed			
	SP1	SP2	SP3	Total*	SP1	SP2	SP3	Total*	SP1	SP2	SP3	Total*
Erythiurina stricta Roxb.									4.10			1.72
Ficus beddomei King.									4.09	5.34		3.40
Ficus recemosa L.									21.26			5.41
Ficus tsjaqhela Burm.f									4.05			1.70
Glochidion zeylanicum (Gaertn) Juss.	6.50			1.98								
Grewia tiliifolia Vahl.	6.28	23.56	22.01	17.51								
Hopea parviflora Bedd.									7.89	22.84	14.84	14.80
Hydnocarpus laurifolia (Dennst.) Sleum.										15.68		4.89
Lagerstroemia microcarpa Wt.	6.40			1.95		7.80		2.55				
Litsea coriacea (Heyne ex Meisner) Hook.f.	11.77		5.25	5.46			6.62	2.10			12.73	3.66
Macaranga peltata (Roxb.) Mueller-Arg.									4.04	5.45		3.41
Mallotus tetracoccus (Roxb.) Kurz.											11.37	3.26
Memecylon edule Roxb.										5.57		1.75
Olea dioica Roxb.		43.00	5.18	15.55	7.12	6.03	5.93	6.34				
Persea macrantha (Nees) Kosterm.	14.87	38.93		16.77								
Phyllanthus emblica L.	6.46		5.23	3.87								
Psidium guajava L.		5.77		1.88								
Pterocarpus marsupium Roxb.			10.28	4.85	24.63	17.15	24.04	21.55				
Sandalum album L.		15.08		4.89								
Sauropus androgynus L.							5.58	3.57				
Semecarpus anacardium L.f..									4.18			1.75
Syzygium gardneri Thw.									51.92	35.87	40.60	44.13
Tabernaemontana gamblei Subram. & Henry in Bull.											6.15	1.77
Tectona grandis L.	58.92	53.77	119.97	79.31	55.14	10.18	25.50	30.49				
Terminalia bellirica (Gaertn.) Roxb.									48.67	51.84	104.3	66.81
Terminalia crenulata Roth.						14.39	45.42	19.02				
Terminalia paniculata Roth.	62.48	25.27	22.69	36.55	81.46	157.22	97.41	111.59		5.75		1.81
Tetrameles nudiflora R.Br									4.06	25.41		9.68
Viburnum acuminatum Wall.ex DC.		23.39		7.22					4.44	6.38	6.78	5.81
Villebrunea integrifolia Gaud.									9.63	8.00		6.44
Walsura pinnata									4.25			1.78
Shrubs												
Allophyllus reedii (Wight) Radlk.	3.69			1.42								
Asparagus racemosus Wild.										32.22		6.29
Chassalia curviflora (Wall.ex Kurz) Thw.						8.72		3.36				
Clausena denata (Wild.) Roem.	24.74	13.54	57.64	38.87								
Croton zeylanicus Muell.-Arg.	18.06			6.17								
Desmodium ferruginenus Wall.ex Thw.		6.32		1.41								
Desmodium gangeticum (L.) DC.					36.47	24.56		22.43	15.77			7.53
Desmodium laxum DC.						6.48		2.56		62.86		11.28
Felicium decipiens Thaw.										32.22		6.29
Glycosmis penataphylla Sensu.					35.27			11.90				
Grewia wightiana Drumm.ex Dunn			3.51	1.41								
Jasminum angustifolium L.										36.15		6.55
Lantana camara L.	75.76	60.80	56.32	61.91	24.75	26.72	22.25	22.77			21.88	7.51
Leea indica (Burm.f.) Merr.			3.52	1.41								
Leea sambucina Wild.									75.69			33.74
Maesa indica (Roxb.) DC.	115.02	171.96	130.85	136.42	91.64	122.48	129.80	113.63	13.45		161.19	59.44
Mallotus tetracoccus (Roxb.) Kurz.									25.06	136.54	109.68	67.77
Memecylon malabaricum (Cl.) Cogn.									13.45		29.13	13.51
Micranthus oppositifolius Wendl.	3.72		23.05	11.15					12.70			6.23
Mimosa pudica L.		17.00		3.80								
Polygonum chinensis L.	11.03			3.87								
Pothomorphe subpeltate Wild.									82.55			39.99
Psidium guajava L.	4.04	6.51	18.08	10.42								
Rubia cordifoila L.			3.51	1.41								
Sarcostigma klenii Wight. &Arn.									15.77			19.53
Sauropus androgynus (L.) Merr.	25.05			6.88	73.34	36.54	50.09	54.97				
Solanum torvum (Sw.,Prodr)	5.27			1.81		6.65		2.62				
Solanum verbascifolium (auct.non L.)									17.52			8.27
Tephrosia purpurea L.		6.32		1.41								

Continued to Table 5

Name of species	Severely disturbed				Moderately disturbed				Undisturbed			
	SP1	SP2	SP3	Total*	SP1	SP2	SP3	Total*	SP1	SP2	SP3	Total*
Thottea siliquosa Lam.									14.58			7.03
Uraria logopoides L.							9.49	2.58				
Vernonia cinerea L.	6.28			2.29								
Vigna trilobata (L.) Verdc.			3.51	1.41								
Wedelia urticaefolia (Blume) DC.	3.64			1.41								
Others					38.53	54.86	88.37	58.03				
Climbers												
Acacia pennata L.							49.59	25.35				
Artabotrys zeylanicus Hook f. & Thoms.									16.98	16.35		10.37
Calamus gamblei Becc.ex Becc & Hook.f.									21.65		12.69	11.62
Celastrus paniculatus Wild.						22.42		6.74				
Cyclea peltate Lam.	67.08		57.70	55.15								
Derris brevipes Bent.										15.12		4.22
Dioscorea pentaphylla L.						22.42		6.74				
Glorisa superba L.						63.60		14.69				
Mikania scandens L.						20.49		6.34				
Piper argyrophyllum (Miq.) Syst.			101.19	64.96	180.36	150.58	220.25	196.84	261.37	268.53	274.21	269.09
Quisquqlis indica L.					56.85			9.57				
Smilax zeylanica L.	152.86		141.11	145.79		20.49		6.34			13.10	4.70
Thunbergia mysorensis (Wight) T.Anders.							30.16	16.32				
Tylophora asmatics Wight& Arg.		300.0		9.71								
Tylophora macranthus Hook.f.					62.79			11.05				
Vigna umbellata Thumb.	80.06			24.39								
Herbs												
Abrus pulchellus Wall.ex Thw	3.54			1.33								
Ageratum conyzoides L.		4.59		1.48		3.45		1.33				
Amomum muricatum Bedd.	20.46		19.49	13.59								
Amomum pterocarpum Thw.					21.63		4.93	7.66				
Asclepias curassavica L.	10.79		6.76	6.04								
Axonopus compressus (Sw.) P. Beauv.	5.03	15.93		7.04		22.63		8.34			11.22	4.13
Carex filicina Nees.	20.88	14.76	6.37	14.39								
Centella asiatica L.		2.93		0.94								
Centrocema pubescens Benth.	2.49			0.94								
Curculigo orchioides Gaertn.			6.14	1.98								
Curcuma pseudomontana Grah.						11.17		4.20				
Curcuma zeodaria (Christm) Rosc.	50.74	47.51	64.19	53.78	23.61	20.03	53.33	33.00				
Cyathula prostrata L.					25.47	68.21	56.85	52.44				
Cyrtococcum patens L.	81.40	90.53	100.72	90.83	110.57	82.88	115.08	101.86	102.87	49.26		46.50
Desmodium gyrans (L.f) DC.						3.72		1.43				
Desmodium styracifolium (Osbeck) Merr.	5.46	3.33	6.53	5.09								
Elephantopus scaber L.	5.24			1.97								
Eupatorium odaratum L.	23.61	54.06	21.51	33.06		3.72		1.43	68.07			26.12
Grewia glabra Bl.											6.33	2.20
Hypoxis aurea Lour.	19.03	14.01		10.57								
Justica procumbens L.					4.75			1.43				
Kyllinga brevifoila Rotb.	3.06	5.00		2.74		5.30		1.98			15.24	5.62
Mimosa pudica L.						3.45		1.33				
Murdania montaum Wight.									5.60			1.84
Oplismenus compositus L.										42.47	89.73	46.33
Panicum montanum Roxb.	3.59		5.02	2.92								
Pennisetum hohenackeri Hochst.ex Steud.	3.67	18.13	10.29	10.38								
Pteris biaurita L.	30.83	5.08	45.29	26.89	78.23	57.55	52.98	61.08	89.71	140.1	125.6	115.25
Setaria palmifolia Koen.										36.21	22.45	19.42
Stachytarpeta jamaicanisis L.	4.02	5.92		3.43		3.72		1.43				
Temeda cymbaria (Roxb.) Hack., DC.										14.58		4.61
Triumfetta rhomboidea Jacq.						3.28		1.27				
Urena lobata L.	6.16	18.21	4.24	9.55	6.32	3.72	11.37	6.95				
Vigna trilobata (L.) Verdc.						3.72		1.43				
Zingiber macrostachyum Dalz.			3.45	1.07	29.41	3.45	5.45	11.42	33.75	17.39	7.53	20.51

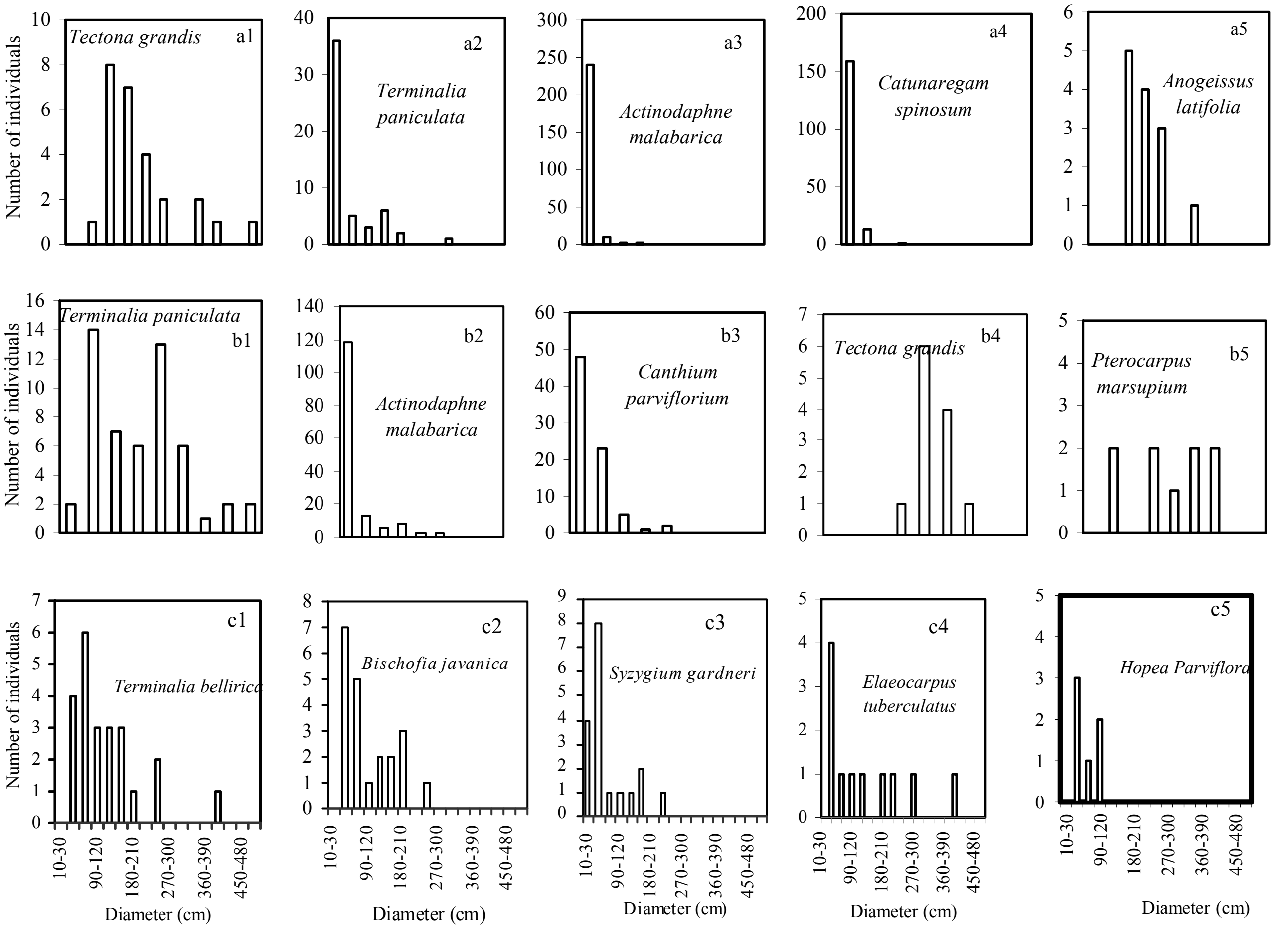

Fig. 2 Diameter class-wise (DBH) distribution of some dominant species in the Site I (a), Site II (b), Site III (c) at Periyar Wildlife Sanctuary in the Western Ghats.

Table 6. Diameter class-wise (DBH) species richness (Number of species) and density (No./0.3ha) of trees (>10 cm DBH) in the tropical forest ecosystems at the Periyar Wildlife Sanctuary in the Western Ghats

Diameter class (cm)	Number of Species			Density		
	Severely disturbed	Moderately disturbed	Undisturbed	Severely disturbed	Moderately disturbed	Undisturbed
10-20	16	8	27	68	61	53
20-30	9	6	11	26	22	32
30-40	7	5	7	24	18	11
40-50	7	7	4	13	28	7
50-60	4	6	3	4	16	6
60-70	1	4	4	1	4	7
70-80	2	2	2	2	2	2
80-90	1	2	3	1	3	4
90-100	-	-	1	-	-	1
100-110	1	-	-	1	-	-
110-120	-	-	-	-	-	-
120-130	-	-	-	-	-	-
130-140	-	-	2	-	-	2

Table 7. Diameter class-wise (DBH) species richness (number of species) and density (No./0.3ha) of juvenile population (>1 - <10cm DBH) in the tropical forest ecosystems at the Periyar Wildlife Sanctuary in the Western Ghats

Diameter class (cm)	Number of Species			Density		
	Severely disturbed	Moderately disturbed	Undisturbed	Severely disturbed	Moderately disturbed	Undisturbed
1-2	10	14	19	450	168	69
2-3	9	14	24	86	117	162
3-4	8	9	11	45	84	77
4-5	6	6	14	30	44	42
5-6	4	5	8	25	425	28
6-7	7	6	6	29	25	16
7-8	6	4	8	24	14	12
8-9	5	2	1	11	2	2
9-10	8	2	3	12	2	3

The species richness of the shrub community was greater in site I compared to the other two study sites (Table 5). The shrub community in site I was dominated by *Maesa indica* followed by *Clausena dentata* and *Micranthus oppositifolius*. Similarly, site

II was dominated by *Maesa indica* followed by *Wedelia urticaefolia, Sauropus androgynus* and *Desmodium gangeticum*. However, in site III, *Mallotus tetracoccus* was the dominant species followed by *Maesa indica, Pothmorphne subpeltate* and *Leea sambunica*. One shrub species was commonly found in all three study areas whereas 13, 3 and 10 shrub species were recorded only in the sites I, II and III respectively. Six species were common between site I and site II. Three species were common between site II and site III. Two species were common between site I and site III.

The number of species in the herbaceous community was greater in the site I compared to the other study sites. *Cyrtococcum patens* was the dominant species in both the study sites I and II followed by *Curcuma zeodaria* and *Eupatorium odoratum* in the site I and *Pteris biaurita* and *Cyathula prostrata* in site II. Whereas in site III, the dominant species was *Pteris biaurita* followed by *Cyrtoccoum patens* and *Oplimenus compositus*. Six species were common among the three study sites. Ten species were common between site I and site II, six species were common between site II and site III and six species were common between site I and site III. 12 herbaceous species were present only in site I and 8 in site II and 6 in site III The number of climbers was low in all the three study areas.

The number of species of sapling populations was greater in site III compared to other study sites (Table 8). Generally dominant tree species showed poor regeneration status in terms of number of sapling population (except *Actinodaphne malabarica)*. We did not encounter saplings of some tree species but found only in adult stage which includes 10 species in site I, 7 species in site II and 22 species in site III. Whereas for 3 species in site I, 18 species in site II and 21 species in site III only saplings were found but not their adult trees. The sapling population of site I was dominated by *Actinodaphne malabarica* followed by *Terminalia paniculata, Catunaregam spinosum* and *Antidesma acidum*. In site II, the dominant species was *Casearia ovata* followed by *Actinodaphne malabarica*, *Grewia tillifolia* and *Canthium parviflorum*, whereas in site III, the dominant species was *Psychotria connata* followed *Clausena dentata, Clausena heptaphylla* and *Villebrunea integrifolia*. Two species in the sapling stage were common to all the three study areas. Forty species in the sapling stage were represented only in one of the three study sites and not in other two.

Table 8. Density (No./0. 025 ha for sub-plots (SP1 – SP3) & N0./0.075 ha for the total) of the saplings (>3 - <10 cm DBH) and Seedlings (<3 cm DBH; values in the parentheses) population recorded in the tropical forest ecosystems at the Periyar Wildlife sanctuary in the Western Ghats, India.

Name of species	Severely disturbed				Moderately disturbed				Undisturbed			
	SP1	SP2	SP3	Total	SP1	SP2	SP3	Total	SP1	SP2	SP3	Total
*Acronychia penduncula*ta (L.) Miq									1		1	2
Actinodaphne malabarica Balakr.	29(60)	36(29)	64(36)	129(125)	18(6)	51(1)	22(25)	91(32)			1	1
Agrostistachys indica Dalz.					(1)			(1)				
Albizzia odoratissima L.f.					(1)	(2)	(1)	(4)				
Allophyllus rheedii (Wight) Radlk.					(1)			(1)	(1)			(1)
Antiderma acidum Retz.	10(14)	2(9)	27(29)	39(52)	3	(1)	(3)	3(4)	1 (1)	(6)	1	2(7)
Antidesma menasu (Tul.) Miq.ex Muell. - Arg.in DC.										1		1
Aporusa acuminate Thaw.		(11)		(11)								
Artocarpus hirsutus Lamk.									1			1
Bridelia roxburghiana Muell. - Arg. Gehm					(1)			(1)		2(3)		2(3)
Callicarpa tomentosa (L.) Murray	(1)			(1)					1			1
Canarium stricum Roxb.					(2)	(1)	1	1(3)				
Canthium parviflorium Lam.					4	4(12)	6(21)	14(33)				
Casearia ovata (Lamk.) Wild.					29(5)	32(7)	62(11)	123(23)		1	10	11
Cassia fistula L.					11(3)	(1)	39(36)	50(40)				
Catunaregam spinosum Thunb.	8(26)	11(29)	25(53)	44(108)	(1)	4(7)		4(8)				
Chionanthus mala-elengi Dennst.	(1)			(1)	(2)	(1)	(1)	(4)				
Cinnamomum malabatrum (Burm.f.) Bl.	1			1					2	2	6	10
Clausena dentata (Wild.) Roem.										(4)	48(3)	48(7)
Clausena heptaphylla (Roxb.) Wight & Arn										7(3)	23(2)	30(5)
Clausena indica (Dalz.) Oliver					(1)		(1)	(2)	2	2		4
Croton bilongiflours Roxb.			(2)	(2)								
Croton malabaricus Bedd.										1		1
Croton zeylanicus Muell. - Arg.									2			2
Cryptocarya anamalayana Gamble.						1		1		1		1
Dalbergia latifolia Grh. Ex. W. & Arn.	(1)	(2)	(6)	(9)		(1)		(1)				
Diospyros microphylla Bedd.	(1)	(1)		(2)	(1)			(1)	(1)	(7)	(2)	(10)
Diospyros sylvatica Roxb.									9			9
Diospyrus neilgherrensis Wight.										1		1

Continued to Table 8

Name of species	Severely disturbed				Moderately disturbed				Undisturbed			
	SP1	SP2	SP3	Total	SP1	SP2	SP3	Total	SP1	SP2	SP3	Total
Dysoxyllum malabarium Bedd.ex Hiern.					6			6	2		1	3
Evodia lunu-ankenda (Gaertn) Merr.						(1)		(1)	(1)			(1)
Ficus amplocarpa Govindarajalu & Masilamoney						(1)		(1)				
Glochidion ellipticum Wight.						1		1			(1)	(1)
Grewia oppositifolia L.											(1)	(1)
Grewia tiliifolia Vahl.	(7)	1(13)	3(59)	4(79)		(1)		(1)				
Helicteres isora L.						22	2(8)	24(8)		4(1)		4(1)
Hydnocarpus laurifolia (Dennst.) Sleum.							1(1)	1(1)	5(1)	6(20)		11(21)
Hydnocarpus pentandra (Buch. - Ham.) Oken										2		2
Ixora globicephata									1			1
Ixora parviflora Vahl.						1	1	2				
Lagerstroemia micricarpa Wt.	(1)	4	1	5(1)								
Litsea oleoides (Meisner) Hook.f.					(1)			(1)				
Litsea coriacea (Heyne ex Meisner) Hook.f.	1(5)	(1)	4(26)	5(32)	(3)	(1)	2(3)	2(7)				
Litsea laevigata (Nees.) Gamble					1			1		(1)		(1)
Macaranga peltata (Roxb.) Muell. Arg.		(1)		(1)								
Mallotus phillippense (Lamk.) Muell. – Arg	(1)		(1)	(2)	(1)			(1)	1			1
Meiogyne pannosa Dalz.		(1)		(1)								
Myristica beddomei King.											1	1
Nothapodytes foetida Wight.							(2)	(2)				
Nothapodytes nimmoniana (Grah.) Mabber.	1		(1)	1(1)						1		1
Olea dioica Roxb.	1(8)	(1)	11(28)	12(37)							1(4)	1(4)
Persea macrantha (Nees.) Kosterm.			10(4)	10(4)	1(8)	3		4(8)		(3)		(3)
Phoebe lanceolata Nees.									3	9	(1)	12(1)
Phyllanthus emblica L.	(1)	(1)	(2)	(4)	(1)			**(1)**				
Psychotria connata Wall.									47(8)	42(6)	50(2)	139(16)
Pterocarpus marsupium Roxb.	(3)	(1)	(8)	(12)								
Sandalum album L.		5		5								
Sarchandra chloranthioides Gard.									3			3
Sterculia guttata Roxb.	(1)			(1)								
Sterculia villosa Roxb.ex DC.			1	1	(1)			(1)				
Stereisoernyn coais (Buch.-Ham.ex Dillw.) Mabber										(1)		(1)
Syzigium cumini L.			(1)	(1)								
Syzigium occidentalis Bourd.					1			1				
Syzygium zeylanicum DC.						1		1				
Tabernaemontana gamblei Subram. & Henry						1		1				
Tectona grandis L.			(1)	(1)						12(1)		12(1)
Terminalia crenulata Roth.											(1)	(1)
Terminalia paniculata Roth.	5(1)	13(15)	37(1)	55(17)	2			2				
Toddalia asiatica (L.) Lamk.									1	1(1)	1	3(1)
Viburnum acuminatum (Wall.ex. DC.)						1		1		(12)	3(1)	3(13)
Villebrunea integrifolia Gaud.										15		15
Xanthophyllum flavescens Roxb.									1	(1)		1(1)
Ziziphus rugosa Lam.					(1)	(1)	1(3)	1(5)				

Dominant tree species also did not show good representation in seedling populations. However, a few species have good regeneration status (Table 8). No seedlings were recorded for 8, 9 and 23 adult tree species respectively in site I, site II and site III. Similarly, seedlings of 13 species in site I, 27 species in site II and 16 species in site III were not represented by any adults. *Actinodaphne malabarica* was the dominant species in the seedling population of site I followed by *Catunaregam spinosum, Grewia tillifolia* and *Antidesma acidum*. In site II, the dominant species in the seedling population was *Cassia fistula* followed by *Canthium parviflorium*, *Actinodaphne malabarica* and *Casearia ovata*, whereas in site III, *Hydnocarpus laurifolia* was the dominant species followed by *Psychotria connata, Villebrunea integrifolia, Clausena dentata* and *Antidesma acidum*. Four species were common in all three study areas. Forty-three species in the

seedling stage were represented only in one of the three study sites and not in the other two.

Discussion

Biodiversity is essential for the survival and economic well-being of humans as well as for the function and stability of the ecosystems. Biodiversity at the global scale is a balance between the rate of speciation and extinction and at the ecosystem level, it is a balance between the rate of invasion and local extinction. The growing awareness of the importance and high rates of biodiversity loss has set a mandate for the rapid assessment and conservation of biodiversity at both regional and global levels (Singh 2002). Biodiversity is unevenly distributed on the earth, with a broad range of global and regional patterns. The uneven distribution of biodiversity was observed at regional and ecosystem levels. Mayers et al. (2000) recognised 25 terrestrial biodiversity hotspots (including 9 leading and 8 hottest hotspots) around the world, which contain a total of 133,149, i.e., 44%, of all vascular plant species. India is one of the top twelve mega diversity centres in the world. The Western Ghats and Eastern Himalayas are the two important centres of biodiversity in India. Tropical forests of the Western Ghats are one of the hottest hotspot in the world, which harbour over 3500 species of flowering plants of the 17000 species described in India (Khoshoo 1995). Of these, 174 plant species occurred in the study area (0.9 ha) of the tropical forest ecosystems at Periyar Wildlife Sanctuary in the Western Ghats. The number of species recorded in the present study is closer to the values reported by Roy et al. (2005) in the Andaman and Nicobar islands. The floristic richness recorded in the value of present study (80–92 species in 0.3 ha) is closer to the values obtained in various regions (12–70 species per 0.1–0.2 ha in Kerala and Karnataka (Pascal 1988); 58–77 species per ha in Kodayar (Sundarapandian 1997); 80–85 species per ha (Parthasarathy 1999); 51–78 species per ha (Ayappan and Parthasarathy 2001); 82–142 species in 0.3 ha Veerapuli and Kalamali reserve forest (Swamy et al. 2000); 4–23 species/ha vindhiyan hill ranges dry tropical forests (Sagar et al. 2003); 22–125 species in 0.5 ha (Sundarapandian et al. 2004); 60 species in 3 ha (Giriraji et al. 2008); 28 to 38 species per ha (Swamy et al 2010); 42–66 species per ha (Rao et al. 2011). The number of tree species (> 10 cm DBH) in tropical forest ecosystems at Periyar Wildlife Sanctuary in the Western Ghats ranged 12–31 per 0.3 ha. These values are at the lower side of the range for wet evergreen forests. The range of tree species counted per hectare was about 20 to a maximum of 223 in tropical rainforests (Whitmore 1975; Proctor et al. 1988).

The endemicity recorded in the present study lies well within the range (2–55%) reported by Ghate et al. (1998) in the entire length of the hill chain of Western Ghats. However, the species *Euodia lunu-ankenda* and *Syzygium zeylanicum* occurred in the study area are listed under IUCN Red list categories of threat in the status of critically endangered species and endangered species respectively (Gopalan and Hentry 2000). In addition, *Derris Brevipes* has come under the status of presumably extinct categories in the above said list. Therefore, the study site requires imminent and stringent conservation strategies to avoid further extinction of above said species and to conserve the natural habitat status.

Tree density in tropical forests varied from 245–859 stems per hectare (Richard 1952; Ashton 1964; Campbell et al. 1992). The density of 443–530 stems per hectare for diameter threshold > 10 cm DBH obtained in the present study is well within the limits reported for tropical forests (Gentry 1988; Chandrashekara and Ramakrishnan 1994; Strasberg 1996; Pascal and Pelissier 1996; Ghate et al. 1998; Swamy et al. 2000; Htun et al. 2011). However, the values were lower than those reported by Pascal (1988) and Jose et al. (1994), in the Western Ghats and Rasingam and Parthasarthy (2009), in the little Andaman Island. The stem basal area in tropical forests at Periyar Wildlife Sanctuary in the Western Ghats ranged between 32.54–49.5 m^2/ha for > 10 cm diameter threshold and were well within the range recorded by others (47.01 m^2/ha, Giriraji et al. 2008; 29 to 42 m^2/ha, Swamy et al. 2010; 17. 8 to 37.8 m^2 /ha, Htun et al. 2011). However, these values were lower than those reported by Singh et al. (102.7 m^2/ha; 1981), Parthasarathy et al. (94.6 m^2/ha; 1992), Sundarapandian and Swamy (81.38 m^2/ha; 2000) and Roy et al. (103.01 m^2/ha; 2005). Difference in density and basal area may be attributed to altitudinal variation (Rai and Proctor 1986), species composition, age structure, successional stage of forest and degree of anthropogenic perturbation as suggested by Sundarapandian (1997).

The Shannon's diversity indices for trees in the present study ranged 1.87–2.55, which was lower than those indices recorded by others in the Western Ghats (4.87, Singh et al. 1981; 2.95, Chandrashekara an Ramakrishnan 1994; 3.37, Ganesh et al. 1996; 2.65, Sundarapandian and Swamy 2000; 2.8, Swamy et al. 2000; 4.89 Giriraji et al. 2008; 3.32–3.86, Didita et al. 2010; 2.939 to 3.957, Rao et al. 2011). Because of the differences in the areas sampled, lack of uniform plot dimensions and standard girth or diameter class makes the comparison difficult. On the other hand, the value obtained for the concentration of dominance for tree layers ranged, 0.12–0.21 in the present study, was greater than those values recorded by Singh et al. (1981), which was closer to earlier reports (Chandrashekara and Ramakrishnan 1994; Sundarapandian and Swamy 2000; Swamy et al. 2000). The diversity index of tree seedlings and saplings and shrubs showed greater values in site III compared to the other study sites (Table 3). However, herbs diversity index was greater in site I compared to the other study sites, whereas the dominance index value showed the reverse trend (Table 3). Variation in diversity and dominance indices among the study sites may be attributed to edge effect, anthropogenic perturbation and associated developmental activities which provide suitable micro environments for herbaceous and shrub community establishment in site I as compared to site III.

The enumerated species belonging to 40–45 families in the present study is within the range of 16–58 families found in tropical forests (Gentry 1988). The values obtained in the present study are at the higher side compared to those recorded by others (Johnston and Gillman 1995; Pascal and Pelissier 1996; Par-

thasarathy and Karthikeyan 1997a). Euphorbiaceae was the dominant family in both site I and site II followed by Papilionatae, Compositae, Graminae, Lauraceae and Verbinaceae in site I and Lauraceae, Rutaceae, Combretaceae and Moraceae in site III, whereas in site II, Lauraceae and Euphorbiaceae were the predominant families in term of number of species. Similarly, Euphorbiaceae was the dominant family in the sacred groves in the southern eastern gats in India (Rao et al. 2011)

Single species such as *T. grandis* (IVI of 80) and *T. paniculata* (IVI of 112), were the dominant tree species in site I and site II respectively, whereas in site III *T. bellirica, B. javanica* and *S. gardneri* shared the dominance. According to Keel and Prance (1979), dominance increases as a function of stress, while Jacobs (1987) holds that in tropical forests dominance by a single species often indicates the past damage. This may be the major reason for single species dominance in both site I and site II. The single species dominance may be due to resource availability on the study sites due to various constrains as observed by He et al. (2010).

Site II is at forest transition level because the site is dominated by both natural species as well as plantation species such as *T. grandis*. This site forms a buffer zone for natural forests and plantations. Cattle grazing and other associated disturbances that alter the micro climate may be the reason for dominance of a single species in site I and site II. However, the disturbance may not be the sole reason for single species dominance. Richards (1952) is of the opinion that adverse climatic conditions may also result in single species dominance.

Rare species (those represented by <2 individuals) accounted for 46–73% of total species occurred in the study areas, which is greater than those found by others elsewhere (40.2%, Manokaran and Kochumen 1987; 26–31%, Parthasarthy and Karthikeyan 1997b). However, the value obtained in the present study is comparable with the values reported by Paijmans (1970), Ho et al. (1987), Gentry (1988) and Swamy et al. (2000)

Many wide spread tropical species tend to be locally abundant in certain areas and relatively rare in others (Hubbell and Faster 1983). This is exemplified by *C. parviflorum, W. urticaefolia* and *S. androgynus* in the present study area where they are abundant with an IVI of 44, 58 and 55 respectively in site II and IVI of only 4.7, 1.4, and 7.7 in site I.

The decrease in stem density with increase in size class of trees observed in the present study is in agreement with other reports (Chandrashekara and Ramakrishnan 1994; Brokaw et al. 1997; Sundarapandian and Swamy 2000; Swamy et al. 2000). This indicated that these forests had no girth class-based selective felling in the recent past and have typical mature stand with good regeneration potential. Similar results were also reported elsewhere (Ho et al. 1987; Lieberman et al. 1985; Swaine et al. 1987; Campbell et al. 1992; Nadkarni et al. 1995). Species richness in terms of the number of species also decreased with increased diameter class. A similar observation was also made by Parthasarathy and Karthikeyan (1997b) and Swamy et al. (2000) in India. The species-level variation in population structure may be attributed to the species preference in site quality, topography, microclimate and forest stature.

An abundant population of tree seedlings and saplings in this forest provides an idea of the regeneration status of different species. On the basis of occurrence of seedlings, saplings and adult tree species, three categories of species are recognised in the present study, (a) those found only as mature trees, and/or saplings without seedlings, (b) those as seedlings without saplings and mature trees, and (c) those as seedlings, saplings and mature trees. However, the seedling and sapling population of dominant species were low representation (no individuals in seedlings and saplings of *T. grandis* and *A. latifolia* in site I and site II, and *T. bellirica* and *B. javanica* in site III). This may be due to microclimate variation and poor regeneration capacity of the seeds. Similarly, lower representation of juveniles for certain primary tree species was reported by Swaine and Hall (1988) in Kade, Ghana. These results are in agreement with the findings of Hubbell (1979), where less abundant species were disproportionately represented by large trees. As observed in the present study, the regeneration of dominant species ranged from 70–1350, 8–808, and 0–1097 in tropical forests respectively at Kakchi (Ganesh et al. 1996), Kodayar (Sundarapandian and Swamy 1997) and Veerapuli and Kalamalai (Swamy et al. 2000) in the Western Ghats.

Anthropogenic disturbances have played an important role not only in creating unhealthy vegetation, but also in altering the structure and species compositions and natural functions of ecosystems (Sundarapandian and Swamy 2000; Swamy et al. 2000; Kalabokidis et al. 2002; Arunachalam et al. 2004; Mishra et al. 2004). The species richness was observed to be lower in site I in comparison to site III, while considering the number and diversity indices of trees, seedlings and saplings, but the trend was reversed when only herbs were taken into account (Table 3). The lower number of tree diversity and species richness could be attributed to anthropogenic perturbation, cattle grazing and other associated disturbances. However, the observations of greater herb diversity in site I may also be due to anthropogenic perturbation, cattle grazing and other associated disturbances. The lower number of species in disturbed sites recorded in the present study is similar to that of earlier studies (Anitha et al. 2009). Disturbance creates an opening, which helps the rural weeds such as *L. camara* and *E. odoratum* to establish. Several studies agreed that the natural or human disturbances provide a good shelter for the establishment and growth of exotic weeds (Whitmore and Burslem 1996; Denslow et al. 2001; Anitha et al. 2009). Exotic plant species such as *L. camara, E. odoratum* and *A. conyzoides* were the dominant species in the disturbed area and open habitat of tropical moist deciduous forests at Periyar Wildlife Sanctuary in the Western Ghats. *L. camara* and *E. odoratum* are only the dominant species in the adjacent teak plantation. Several interacting factors have contributed to the successful colonization by exotic plant species in disturbed forest lands. Thus, it is reasonable to expect a high degree of invasion in an open habitat with reduced competition created by a human disturbance in the area (Site I) as compared to undisturbed area (site III). Exotic plant species produce abundant seeds that are dispersed by wind and birds, and also propagate through vegetative means (Ramakrishnan 1992). In many open areas of disturbed

sites *L. camara* and *E. odoratum* co-existed, where two or more exotic species co-existed in the same area, this co-existence is due to the practice of mutual avoidance (Ramakrishnan 1991). This is an important attribute of exotic invaders in the wide ecological amplitude, either through extreme phenotypic plasticity or due to ecological races adapted to specific habitat (Ramakrishnan 1991) and also allopathic properties of exotic invader that confer upon them a distinct edge over the existing native species. In addition to that these alien plants are not normally consumed by cattle which prefer the palatable native species (Lal and Karia 1969). The high dominance of exotic species in severely disturbed and moderately disturbed areas may be attributed to above reasons.

The present study reveals that anthropogenic perturbances provide an opportunity for exotic plant invasion as well as reduce the species richness, which inhibits the regeneration of native species. Exotic plant invasion resulted in the loss of local biodiversity. Since anthropogenic perturbances are minimized in the maintenance of plantations and give more priority to the conservation of natural vegetation at Periyar Wildlife Sanctuary in the Western Ghats by forest authorities, site II has a good secondary forest with potential natural regeneration status. If the same situation prevails, site II might become a thick semi-evergreen forest in due course of time. Similarly, in due course of time, if the anthropogenic perturbations are minimized or completely stopped, site I might become a transitional zone and might later develop into natural forest. However, the forest plantations which are adjacent to the study sites are dominated only by *T. grandis*, while the understory vegetation is occupied by mostly exotic species such as *L. camara* and *E. odoratum.* Thus, results from the present study call for formal actions from the concerned government agencies to eradicate the exotic species as well as to stop further invasions in order to restore native species and to avoid local biodiversity loss in the Periyar Tiger Reserve.

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